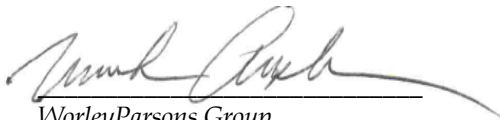

Plan to Conduct Step-Rate Test (SRT) and Initial Fall-Off Test (FOT)


In Accordance with EPA
Underground Injection Control (UIC)
Permit No. R9UIC-CA5-FY13-1

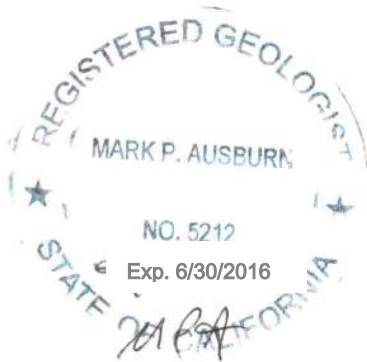
PG&E Compressed Air Energy Storage Project
Compression Testing Program
King Island Gas Field, San Joaquin County, California
September 25, 2014

CERTIFICATION

This report has been prepared by Alan Burzlaff, P.E., as an employee of MHA Petroleum Consultants and with expertise in petroleum engineering and reservoir engineering; under the review and supervision of Mark Ausburn, P.G., as an employee of WorleyParsons, and with expertise in petroleum geology. Their signatures and stamps appear below. The findings, recommendations, specifications and/or professional opinions presented herein have been prepared in accordance with generally accepted professional geologic and engineering practice for similar projects, and within the scope of the project. There is no other warrantee, either express or implied.


WorleyParsons Group
Mark Ausburn, P.G.
Senior Supervising Geologist


MHA Petroleum Consultants
Alan Burzlaff, P.E.
President MHA California



**UIC Step-Rate Test and Initial Fall-Off Test Procedure
PG&E CAES Test Injection/Withdrawal (I/W) Well
King Island Gas Field, San Joaquin County, California**

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EXHIBITS

- 1 Proposed Well Construction Design at Time of Step Rate Test
- 2 Step Rate Test Data Reporting Form

**UIC Step-Rate Test and Initial Fall-Off Test Procedure
PG&E CAES Test Injection/Withdrawal (I/W) Well
King Island Gas Field, San Joaquin County, California**

1. Introduction

This procedure is prepared to comply with the United States Environmental Protection Agency (EPA) requirements for injection well testing in a permitted Class V experimental compressed air energy storage (CAES) injection/withdrawal (I/W) test well. The purpose of this document is to provide a plan for the acquisition of a Step Rate Test (SRT) and initial Pressure Falloff Test (FOT) under UIC Permit No. R9UIC-CA5-FY13-1.

Three documents were used in preparing this procedure:

- EPA Region 8 Step Rate Test Procedure, January 12, 1999;
- Society of Petroleum Engineers (SPE) paper #16798, Systematic Design and Analysis of Step-Rate Tests to Determine Formation Parting Pressure, Singh et al., 1987, and;
- EPA Region 9 UIC Pressure Falloff Requirements, August 8, 2002.

The SRT will be conducted in accordance with Section B, paragraph 3.b and Appendix F (Region 9 Step Rate Test Policy) of UIC Permit No. R9UIC-CA5-FY13-1. The Region 9 Step Rate Test Policy makes reference to SPE Paper #16798 and EPA Region 8 SRT Procedure incorporates the SRT guidance from this technical paper. The SRT will be conducted using 4% KCL water and service company injection pump trucks.

The initial FOT will immediately follow the SRT and will be conducted in accordance with Section B, paragraph 3.c and Appendix E (Region 9 UIC Pressure Falloff Requirements) of UIC Permit No. R9UIC-CA5-FY13-1. The Region 9 UIC Pressure Falloff Requirements, dated August 8, 2002, is a condensed version of EPA Region 6 UIC Pressure Falloff Testing Guideline, Third Revision.

2. Test Well Information

A SRT will be conducted for King Island I/W Test Well, Piacentine 3-27, API #077-20739. The purpose is to establish the maximum injection pressure under Section D, paragraph 3 of the UIC Permit. The test interval will be an open borehole, drilled ten

(10) feet below the 9-5/8" casing shoe (set at approximately 4730' MD or 4681' TVD) into the Mokelumne River Formation (MRF) injection zone, prior to final well completion and before continuous injection is authorized by EPA. Water injection will be through 4 1/2", 16.6# open-ended drill pipe. The ground elevation is -3.75' and KB elevation is 8.25' above ground. A wellbore diagram is provided in **EXHIBIT 1**.

3. Pre-Testing Preparation

Prior to commencing the SRT test procedure, the following tasks will be performed to prepare for the tests:

- Inspect the selected test well to verify the presence and good working condition of a crown valve with sufficient internal diameter that will allow passage of the pressure gauge tools through drill pipe and an open BOP.
- Verify that the injection interval is not covered by fill material. This will be accomplished while running the bottomhole gauges.
- Mobilize pumping equipment capable of delivering a range of water injection rates from 0.5 barrels per minute (BPM) to 15.0 BPM. The amount of clean filtered 4% KCL water required for testing has been estimated at 3,795 barrels, but due to the uncertainty of actual injectivity, additional capacity is planned, at least 4,000 barrels total (205 bbl contingency). The density and viscosity of the fluid will be measured.
- Obtain a calibrated turbine flow meter or set of meters to measure the full range of planned injection rates. Two flow meters may be necessary to measure the lowest and highest planned rates.

4. Pre-SRT Activities

The I/W well will be shut-in at least two (2) hours prior to the SRT, long enough for the bottomhole pressure to be approximately equal to the shut-in static formation pressure. The adjacent well (Piacentine 1-27) to the I/W test well should be shut-in at least one day prior to and remain shut-in during the SRT.

Run open-ended drill pipe to 4720' MD. Close pipe rams and bag. Install circulating head with 2" wing valve and 2" top valve. Rig up wireline truck and install lubricator on top of circulating head. Set up surface recording gauges. Run in hole with downhole pressure test tools prior to starting the step rate test injection increments. Test equipment will include the following considerations:

- Pressure test instruments equipped with two digital quartz gauges each with a minimum accuracy of 0.01 pounds per square inch absolute (psia). The second gauge will serve as a backup. The electronic gauges will be calibrated according to the manufacturer's recommendations. The maximum gauge limit should be close to, but not less than, the estimated maximum bottomhole pressure during the test of 4,300 psi (2,200 psi surface);
- Tag bottom and record depth of hole;
- Set digital pressure/temperature gauges just inside the bottom of the 4 ½" drill pipe which is near the base of the surface casing and top of the effective completion interval; and
- Measure reservoir pressure at frequent intervals. The data sampling frequency will be set at the maximum possible frequency (1-second intervals).

Accurate recordkeeping of injection rates and surface pressures for the test well will be maintained on a test data reporting form (see attached example from EPA Region 8 Step Rate Test Procedure – **EXHIBIT 2**).

5. SRT Injection Procedure

- 1) Move in service company pump truck, connect to drill pipe and conduct a series of successively higher injection rates using the guidelines below. Rates will be initiated with the 20% rate and will be held constant for 30 minutes for the first step and for 30 minutes each for all other steps, progressing upwards to the next higher planned rate. The final step in the SRT will be extended to at least 2 hours in duration to ensure that the final injection rate reaches the radial flow regime prior to shut-in for the FOT period. The starting time, elapsed time and pressure values will be read and recorded for each rate and time step.
- 2) Injection rates planned for the test are defined in the following table. Included are: rate as a percentage of the anticipated maximum injection rate, step duration in minutes, barrels water injected per day (BWIPD), barrels per minute (BPM), gallons per minute (GPM), and total barrels per step (BBL). The size of the rate steps may be adjusted as directed by the PG&E drilling engineer and by EPA to account for actual rate versus pressure behavior encountered during the injection period.

PG&E CAES Project
 Permit No. R9UIC-CA5-FY13-1
 Step-Rate Test and Initial Fall-Off Test Procedure

Step	% Max Rate	Minutes	BWIPD	BPM	GPM	BBL
1	20	30	2,880	2.0	84	60
2	40	30	5,760	4.0	168	120
3	60	30	8,640	6.0	252	180
4	80	30	11,520	8.0	336	240
5	100	30	14,400	10.0	420	300
6	110	30	15,840	11.0	462	330
7	120	30	17,280	12.0	504	360

Subtotal 1,590

Optional Steps if needed

8	135	30	19,440	13.5	567	405
9	150	120	21,600	15.0	630	1,800

Total w/ Optional Steps 3,795

Contingency 205

Grand Total 4,000

Injection rate versus surface pressure is to be plotted during the testing to determine the surface breakdown pressure and rate. The 110% and 120% rates above are to be conducted to obtain three step rates above the fracture pressure.

- 3) Injection rates will be controlled with a constant flow regulator that has been tested prior to use. A throttling device is not sufficient for this test.
- 4) Flow rates will be measured with the calibrated turbine flowmeters that are tested prior to the SRT.
- 5) Digital recording of injection rates versus time is needed.

- 6) Pressures will be recorded at the surface with a wellhead pressure gauge and at the bottomhole with the downhole pressure gauges. A plot of stabilized injection pressures versus injection rate will be used to determine fracture pressure based on a slope change on the plot. This value will be compared to the ISIP measured on the well with both the surface and bottomhole gauges for validation.
- 7) Synchronizing of injection rate, surface tubing pressure, and bottomhole pressures is to be conducted so that all data can be recorded and reported on a common time basis.
- 8) Once the formation fracture pressure is exceeded, as evidenced by at least three injection rate-pressure combinations greater than the breakdown pressure, the injection pump will be stopped. If this is not the case, then one to two additional step rates will be conducted to ensure rates above fracture pressure. In the event that the formation breakdown pressure is not observed for the maximum test injection rate utilized, the maximum allowable injection pressure (MAIP) would be based on the final step injection pressure.
- 9) **MAIP Determination.** The MAIP will be stated as a bottomhole pressure but will be based on a measured wellhead pressure that is equivalent to the bottomhole MAIP when injecting nitrogen during CAES injection operations.
- 10) **ISIP Determination.** At cessation of the highest injection rate period, shut down the pump and close the surface tubing head or line valve so as not to isolate the surface and downhole gauges. Continue monitoring surface pressures for two hours to allow for determination of Instantaneous Shut-in Pressure (ISIP). The ISIP is the minimum pressure required to hold open a fracture and is thus a check on the fracture pressure to be determined from the cross-plot of pressure versus rate.
- 11) **Fall-off Test Objective.** Keep the well shut-in at the surface overnight to record the pressure falloff. A proposed shut-in time of 12 hours will be sufficient to observe the radial flow regime for the injection zone and to extrapolate the data to static reservoir pressure from the bottomhole gauges.
- 12) Retrieve bottomhole gauges, then the surface gauges to complete the SRT.

6. Fall-off Test Analysis

The pressure data for the FOT will be analyzed in accordance with EPA Region 9 FOT Requirements, adjusted as needed for site-specific parameters.

7. Analysis and Report

A plot of injection rates and the corresponding stabilized pressure values will be represented graphically as a constant slope straight line to a point at which the formation fracture, or breakdown, pressure is exceeded. The slope of this subsequent straight line should be less than that of the before-fracture straight line.

Breakdown pressure should be determined using both surface and bottomhole pressure data on the above described plot. Additionally these values will be compared to the ISIP from the test. This procedure is consistent with EPA Region 9 Step Rate Test Policy based on SPE technical paper #16798.

The report to EPA will provide 1) general information, 2) an overview of the SRT and FOT, 3) an analysis of the injection pressure-rate data and estimated fracture pressure obtained during the SRT, and 4) analysis of the FOT pressure data including determination of the formation transmissivity, radius of investigation and skin factor (wellbore damage).

EXHIBIT 1

Proposed Well Construction Design At Time of Step Rate Test

Operator: PG&E
Field: King Island
Lease:
Well: I/W Test Well 1

Drawing Date: 7/8/2014
Spud Date: TBD
Abandonment Date:

Sec 27, T3N, R5E, MD B&M

All depths measured from KB (except P/A plugs)

KB: 12'

API #: TBD

Hole Size	Depth
	0'-60'
17.5"	60'-600'
12.25"	600'-4730'
8.75"	4730'-4963'

20" 53# Cond. Cmt. @ 60'

Perforations	Slots / Hpf	Date Opened	Date Closed
Openhole ~ 10'			

13.375" 154# J-55 LTC cmt'd @ 600'
Cmt w/ 440 sx Woodland Light
Class "G" cmt, lead 290 sx
w/ 13.1# 1.716 cf/sk; tail w/
150 sx Class "G" w/ 14.5#
1.423 cf/sk

Formation (top)	MD	TVD
T/Mokelumne River (est.)	4730'	4681'

Fish

9.625" 40# J-55 & N-80 LTC @ 4730'
Cmt'd w/ 1330 sx cement,
lead w/ 980 sx Light Cement,
tail w/ 350 sx Premium Cement
@ 16.2 ppg

Plugs	Date	Cement
4740'-4963'		120 sx "G"

TD @ 4963'

EXHIBIT 2

Step Rate Test Data Reporting Form

STEP RATE TEST DATA

Well: _____ Date: _____ Operator _____

STEP #1 Test Rate (5% of maximum rate) _____ (bbl/min)

Time (min) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #2 Test Rate (10% of maximum rate) _____ (bbl/min)

Time (min) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #3 Test Rate (20% of maximum rate) _____ (bbl/min)

Time (min) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #4 Test Rate (40% of maximum rate) _____ (bbl/min)

Time (min) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #5 Test Rate (60% of maximum rate) _____ (bbl/min)

Time (min) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #6 Test Rate (80% of maximum rate) _____ (bbl/min)

Time (min) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

STEP #7 Test Rate (100% of maximum rate) _____ (bbl/min)

Time (min) :	_____	_____	_____	_____	_____	_____	_____
Pressure (psi):	_____	_____	_____	_____	_____	_____	_____

ISIP : _____ (psi)

Test Run / Witnessed By: _____